‘Advanced Control Systems for the Grid’ and DER

CADER International Symposium
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How ‘Advanced Control Systems for the Grid’ may affect DER

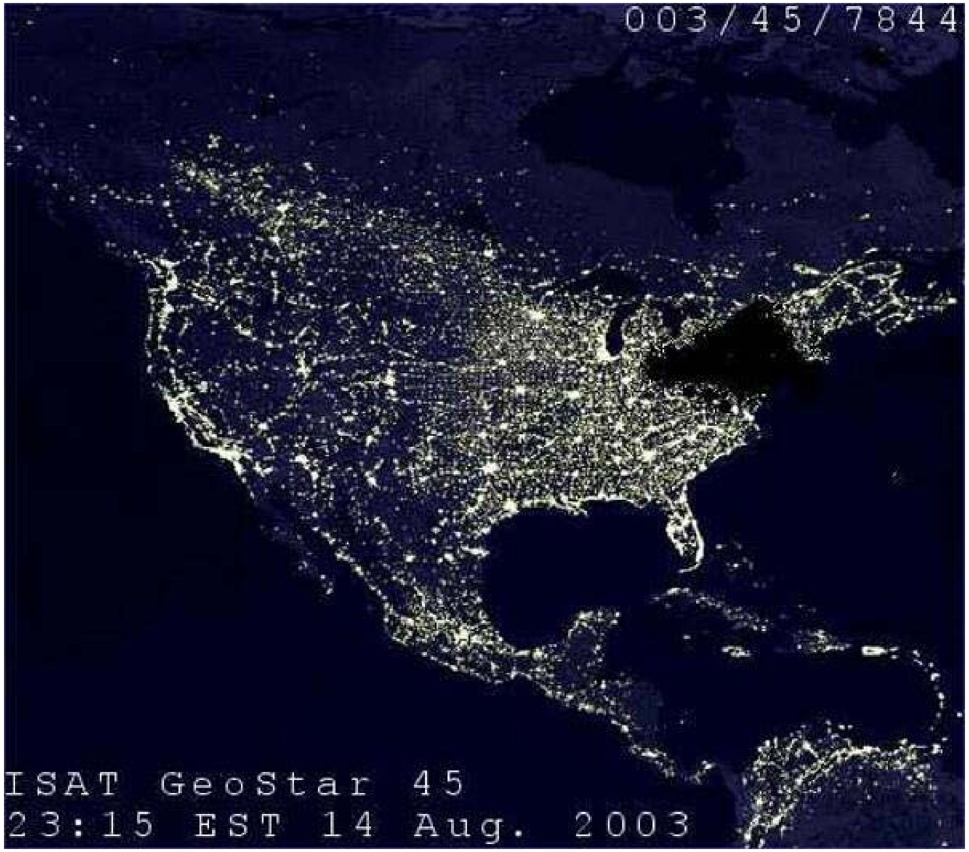
1. **Reactive Power Management and Voltage Support are becoming a big deal for power networks.**

2. **Distributed Energy Resources are uniquely valuable as reactive power sources:**
   - **Distributed (many and small)**
   - **Local (close to need)**
   - **Variable output (responsive)**

3. **Advanced grid controls should rely on DER as dynamic reactive power sources embedded in the power delivery system**

4. **Potential significant commercial and technical implications for DER users, vendors, project developers, and policymakers.**

Insufficient transmission capacity?



- **Inadequate tree-trimming?**
- **Poor operator training?**

NERC Blackout Response

NORTH AMERICAN ELECTRIC RELIABILITY COUNCIL

Near-Term Industry Actions

- Voltage support/reactive supply
- Reliability communications
- Computer failure response & notifications
- Emergency action plans & capabilities
- Operator training for emergencies
- Vegetation management

D. Nevius, D. Cook, et al, *FERC and Regional Efforts to Ensure Reliability,* p. 15

FERC Blackout Response

- **Among other things, a study of the adequacy of the Midwest transmission system.**

- **"In particular, the study will cover the following:**
  1. **Minimum acceptable pre-contingency voltages;**
  2. **Reactive power margin requirements; …"**

    -- FERC directive to FirstEnergy to study adequacy of transmission facilities

It's not just the 2003 Northeast Blackout

- **"Voltage drops related to reactive power caused blackouts on the Pacific Coast in 1996 and in France in 1978. PJM itself came close to a blackout due to reactive power problems in 1999, avoided it, and took corrective steps. Yet, by having rigorous regional monitoring of reactive power and rules for its operation and compensation, PJM is unusual within the electric industry."**

  -- *PennFuture*[3], October 2, 2003

- **"On June 14, 2000 the Bay Area System in fact had sufficient generation and other resources (including transmission and distribution resources) to have withstood voltage collapse without any load shedding. Poor system distribution of reactive power resources as well as real power resources contributed substantially to impending voltage collapse under June 14 loads."**

  -- Optimal Technologies, *Operations Review of June 14, 2000 Outage.*

Reactive Power, Voltage, and DER

- **"Reactive power can be transmitted over only relatively short distances, and thus must be supplied as needed from nearby generators or capacitor banks. If reactive power cannot be supplied promptly and in sufficient quantity, voltages decay and in extreme cases 'voltage collapse' may result."**

  -- Joint US-Canada Interim Blackout Report

- **Reactive capacity is important for reliable power network operation.**

- **The economic cost of voltage collapse is high, but the value of resources that can prevent it is hard to price.**

- **The most valuable sources of reactive power are:**
  - **Close to reactive loads**
  - **Responsive to network conditions**

Optimal Portfolio Methodology for Assessing DER Benefits for Grid

- **Quantify and price the potential benefits of DER (demand response, DG, and capacitors) to power delivery networks:**
- **Analyze the power delivery network where DER projects are actually connected, with transmission and distribution as an *integrated* power delivery network (Energynet).**
- **Consider DR *and* DG *and* capacitors as available DER options to improve network performance.**
- **Observe the impacts of DER on a broad set of network performance indicators.**
- **Optimal Technologies' AEMPFAST® network optimization software.**
  - Direct voltage optimization => ideal settings of controllable variables and precise placement of real and reactive capacity additions through DER.

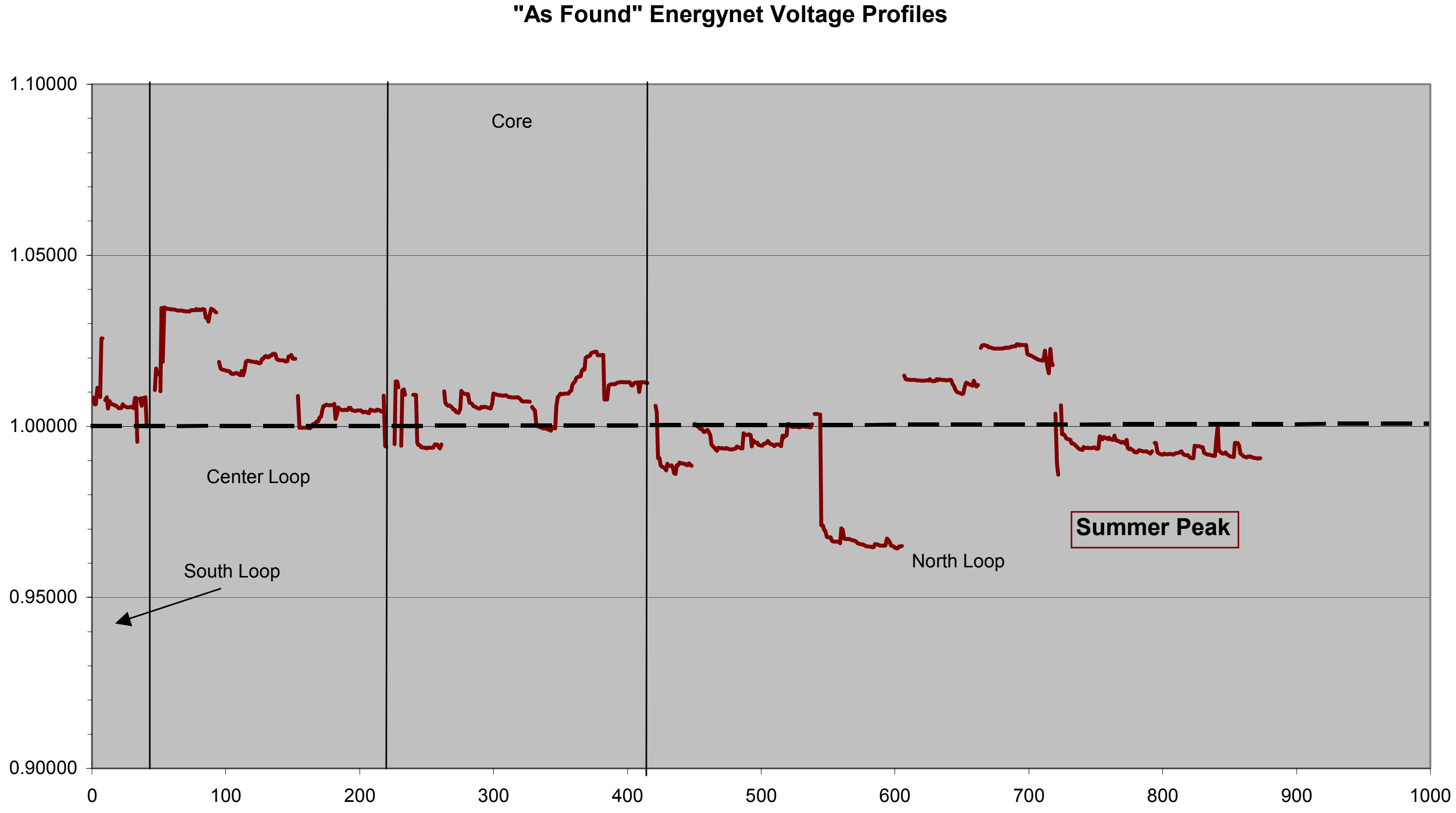
Certain features U.S. Pat. Pend.

Analyzing an Integrated Power Delivery System

- **Silicon Valley Power:**
  - ~ 850 bus network
  - 12 kV distribution integrated with 60 kV and 115kV transmission as single system.
  - 48 12kV distribution feeders connected by 106 switchable branches.
  - 422 load customer-serving buses – customer transformers and customers at primary-voltage service.
  - 101 switchable capacitors.
  - 6 generators with variable MW and MVAr capacity
  - Customer loads and generation from actual 2002 SCADA records.
  - Fully-integrated into PG&E regional 115 kV and 230 kV transmission and ~13,000 bus WECC west-wide high-voltage transmission system.

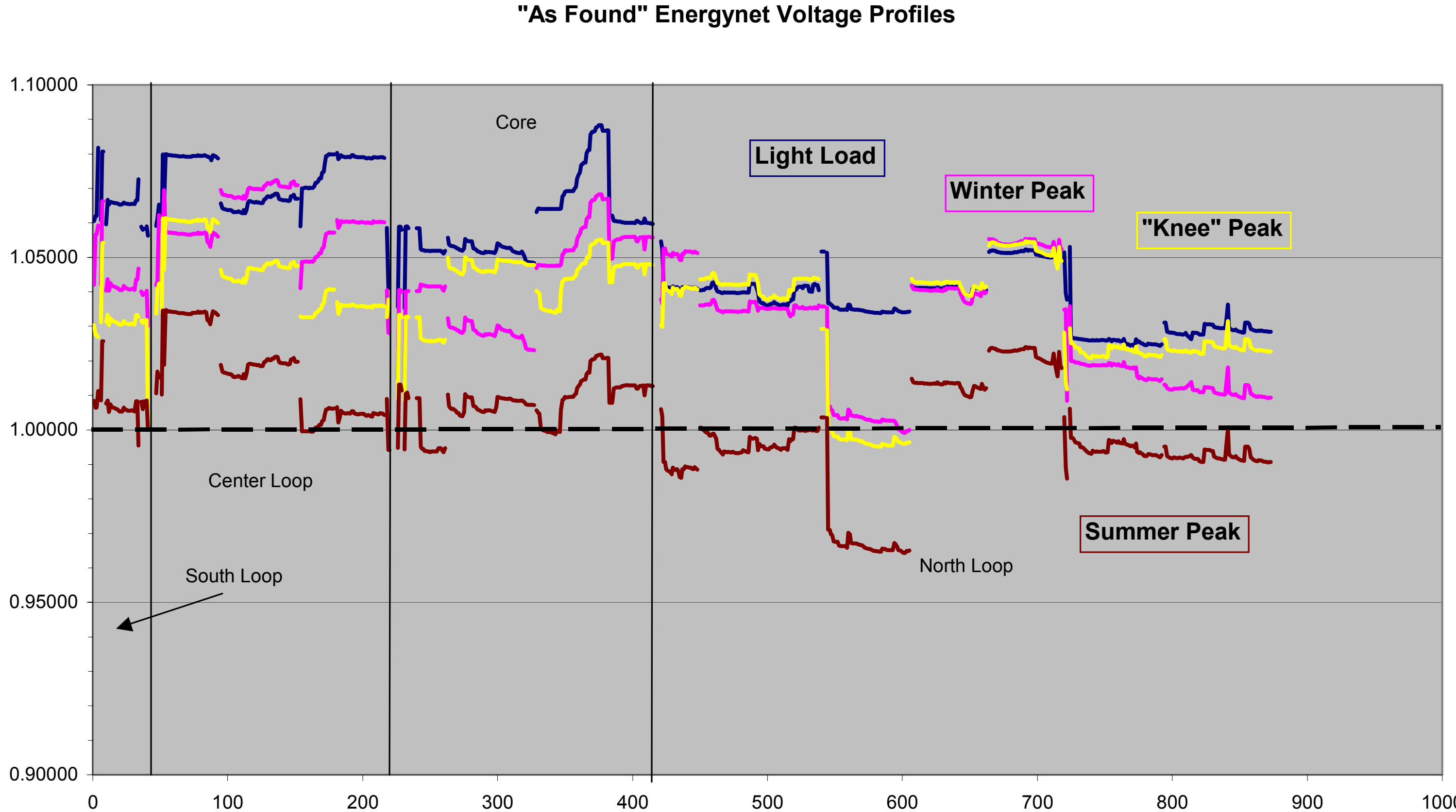
Results from initial demonstration funded by California Energy Commission, PIER Project 500-01-039

Integrated SVP Network's "As Found" Voltage Profile



- All buses within +/- 5% of rated voltage under peak load conditions – a healthy system.
- Voltage variability at both distribution and transmission levels.

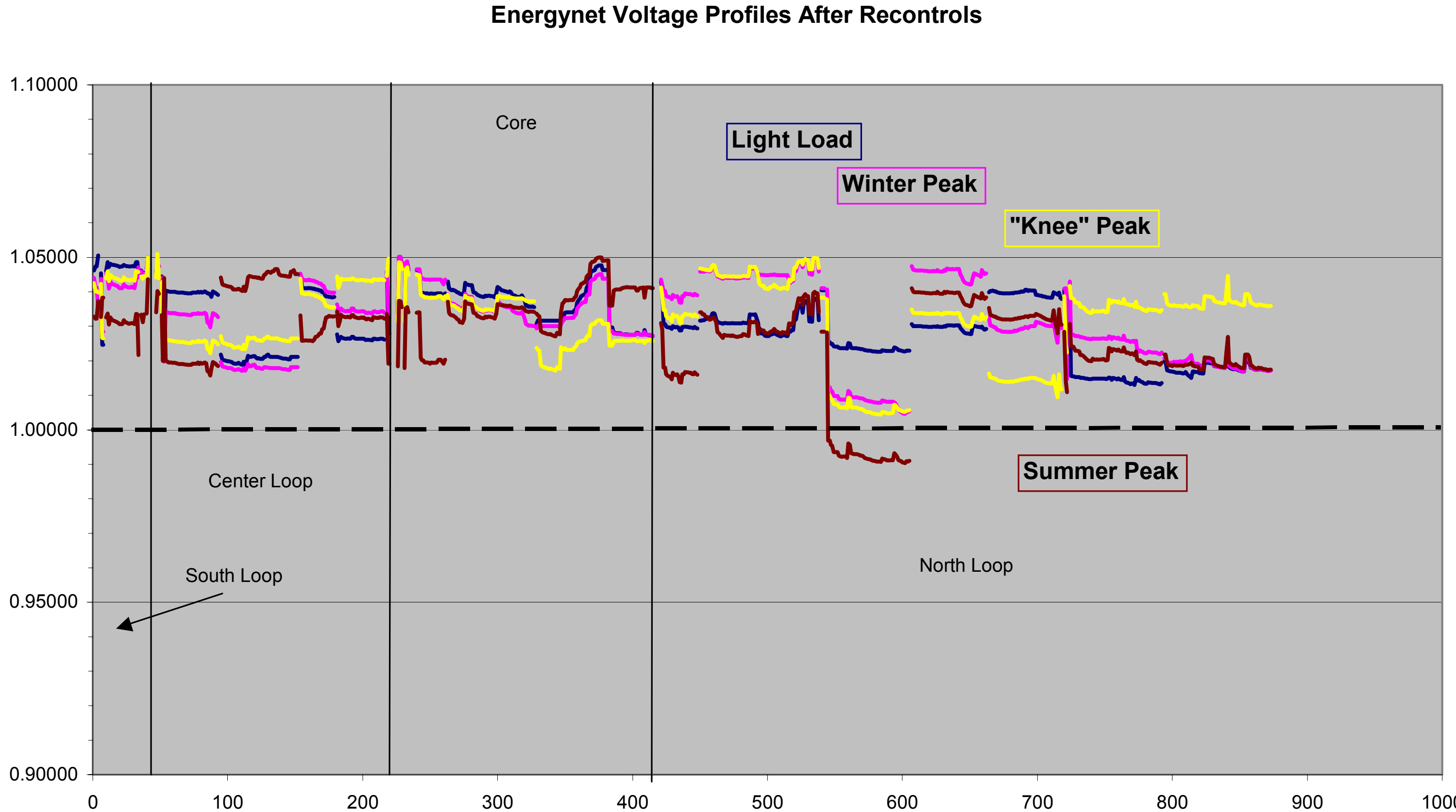
“As Found” Voltage Profiles Under Different Load Conditions



– **Incorporates normal operation of scheduled pole and station capacitors.**

- **Significant seasonal variation and variation around system.**
- **Summer Peak is atypical.**

Redistributing reactive sources improves voltage profiles.

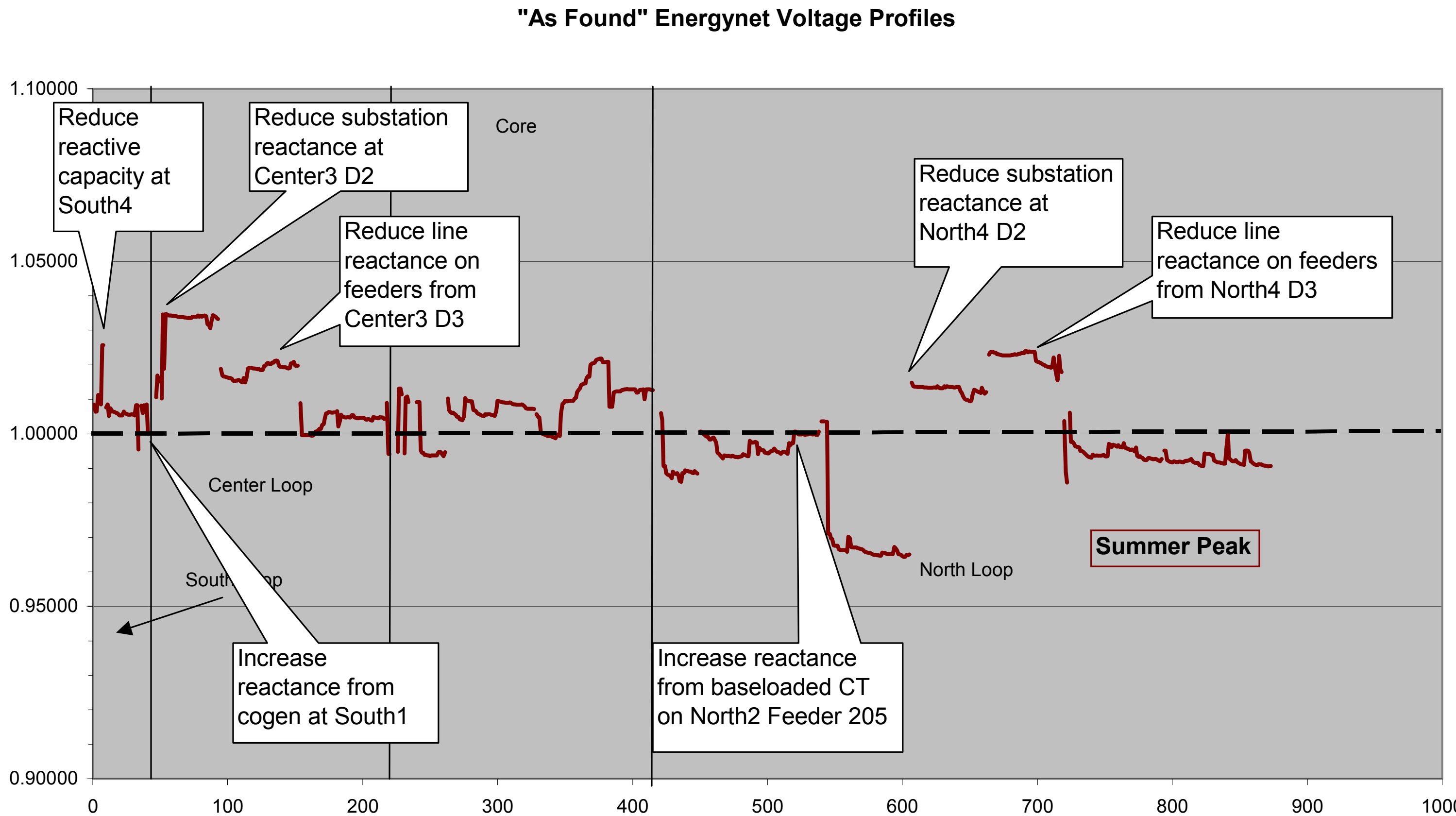


- “Objective:” Minimize real power losses and reactive power consumption while minimizing voltage deviation.
- Recontrol also reduces losses by up to 5.8%.

What did we change?

- **No MW output change from embedded generators.**
- **No removal of loads or addition of resources.**
- **Different configuration of reactive (VAr) sources under each load condition.**
  - **Embedded (distributed) generation units' MVAr output changed.**
  - **Capacitors switched on or off**
- **Results from AEMPFAST analysis.**

Recontrol Changes – Summer Peak Case



Recontrol Changes – Embedded Generation

					Recontrol Q Change (MVAr)			
Output Bus	**Name**	**Substation**	**Feeder**	**Pmax (MW)**	**Light Load**	**Winter Peak**	**Knee Peak**	**Summer Peak**
16	34LGEN1	Core1	Feeder 304	3.5	(1.1)			
17	34LGEN2	Core1	Feeder 304	3.5	(1.1)			
8509	25AGEN1	North2	Feeder 205	1.5		1.0		1.3
36622	QF	South1	Substation	25.0	1.7	3.6	9.2	4.7
36655	GIANERA	North3	Substation	19.5	Not Operating	- >		
36656	GIANERA	North3	Substation	19.5	Not Operating	- >		

- **Different VAr output configuration for each load condition.**

Recontrol Changes – Capacitors

South Loop Capacitors

Bus	Substation	Feeder	Reactance (MVAr)	Light Load Change	Winter Peak Change	Knee Peak Change	Summer Peak Change
3	South3	D1 - Substation	0.012	Switch Off	Switch Off		
36659	South3	D2 - Feeders	3 x 0.012	Switch Off 3	Switch Off 1		
36651	South4	Feeders	7 x 0.012	Switch Off 6	Switch Off 6	Switch Off 6	Switch Off 2
36635	South5	D1 - Feeders	5 x 0.012		Switch Off 4		
36636	South5	D2 - Feeders	8 x 0.012	Switch Off 4	Switch Off 6		

Center Loop Capacitors

Bus	Substation	Feeder	Reactance (MVAr)	Light Load Change	Winter Peak Change	Knee Peak Change	Summer Peak Change
1062	Center2	Feeder 104	0.012	Switch Off	Switch Off	Switch Off	
1083	Center2	Feeder 203	0.012		Switch Off		
14	Center2	D1 - Feeders	6 x 0.012	Switch Off 2	Switch Off 1		
15	Center2	D2 - Feeders	13 x 0.012	Switch Off 7	Switch Off 5	Switch Off	
1047	Center3	Feeder 303	0.012	Switch Off	Switch Off	Switch Off	
1048	Center3	Feeder 303	0.012		Switch Off		
1049	Center3	Feeder 303	0.012	Switch Off	Switch Off	Switch Off	
12	Center3	D2 - Feeders	0.012	Switch Off	Switch Off	Switch Off	
12	Center3	D2, Substation	2 x 0.048	Switch Off 1	Switch Off 1	Switch Off 2	Switch Off 2
13	Center3	D3, Substation	2 x 0.048	Switch Off 1	Switch Off 2	Switch Off 1	
36653	Center4	D2 - Feeders	4 x 0.012	Switch Off 1	Switch Off 4	Switch Off 2	

– **Different VAr output configuration for each load condition.**

Recontrol Changes – Capacitors (cont.)

"Core" Capacitors

Bus	Substation	Feeder	Reactance (MVAr)	Light Load Change	Winter Peak Change	Knee Peak Change	Summer Peak Change
2502	Core1	Feeder 302	0.048				
2501	Core1	Feeder 204	0.048			Switch Off	
1091	Core1	Feeder 304	0.012	Switch Off	Switch Off	Switch Off	
1092	Core1	Feeder 304	0.012	Switch Off	Switch Off	Switch Off	
1093	Core1	Feeder 304	0.012			Switch Off	
1094	Core1	Feeder 304	0.012	*		Switch Off	
1095	Core1	Feeder 304	0.012			Switch Off	
1021	Core1	Feeder 305	0.012	*	Switch Off	Switch Off	
1022	Core1	Feeder 305	0.012	*	Switch Off		
6	Core1	D1 - Feeders	0.012		Switch Off		
7	Core1	D2 - Feeders	0.012			Switch Off	
8	Core1	D3 - Feeders	3 x 0.012				

* Timer operated; switched off.

North Loop Capacitors

Bus	Substation	Feeder	Reactance (MVAr)	Light Load Change	Winter Peak Change	Knee Peak Change	Summer Peak Change
1000	North2	Feeder 202	0.012				
1001	North2	Feeder 202	0.012			Switch Off	
1	North2	D1 - Substation	0.048		Switch Off	Switch Off	
2	North2	D2 - Feeders	0.012			Switch Off	
1039	North4	Feeder 301	0.012		Switch Off	Switch Off	Switch Off
1037	North4	Feeder 301	0.012				Switch Off
1038	North4	Feeder 301	0.012		Switch Off	Switch Off	Switch Off
9	North4	D1 - Substation	0.012				
10	North4	D2 - Substation	0.048			Switch Off	
11	North4	D3 - Substation	2 x 0.048		Switch Off 1	Switch Off 2	
4	North6	D1 - Substation	2 x 0.048				
5	North6	D2 - Substation	0.048				

– **Different VAr output configuration for each load condition.**

Observations

- **Different reactive power (VAr) output configurations are optimal under each load condition.**

- **Small, widely dispersed reactive power sources increase network operational flexibility.**

- **Reactive sources are more valuable if they are directly controllable by network operators as load conditions change.**

Implications for DER

Technology

- DG might be more valuable if it can also serve as a dynamic reactive source for the network.
- Advanced real-time, two-way, content-rich monitoring and controls connecting DER with the network operator.

Commercial

- 'Advanced' network control of DG might be limited to just units' reactive output when they are running.
- Need to compensate customers for providing dynamic reactive power from customer-owned generation.

Conclusion

- **Pay attention to advanced grid controls for reactive power management and voltage support in power networks.**

- **These may have a dramatic affect on DER technology and the commercial prospects for DER.**

About New Power Technologies

- **New Power Technologies identifies and develops businesses and technologies enabling an intelligent energy infrastructure.**

- **Our core belief is that the electric power infrastructure of the future is an Energynet^{SM} comprised of:**
  - Integrated transmission and distribution
  - Embedded (or "distributed") generation with remote generation
  - Loads responsive to network conditions
  - Energy services mass customized to meet customer needs

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